16-400052

DIGI-CAL® III

AN6503
DIGITAL THERMOCOUPLE INSTRUMENT THERMOMETER/CALIBRATOR

AN6501, AN6502
DIGITAL THERMOCOUPLE THERMOMETER

MP MASTER
MA29924

ANALOGIC®

16-400052

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DIGITAL THERMOCOUPLE INSTRUMENT
THERMOMETER/CALIBRATOR

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ANALOGIC®

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Refer to WARRANTY on inside back cover for further details.

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AN6501
TEMP °F
T1 T2 °F
2500.8
BAT mV
AN6502
T1 T2 °C °F
99.998
PEAK BAT mV HOLD
PEAK
°C / °F
HOLD
AN6503
T1 T2 °C °F
3307.0
PEAK BAT CAL mV HOLD
FAST
CAL
PEAK
°C / °F
HOLD

Chapter 1
INTRODUCTION

1.1 GENERAL DESCRIPTION

The DIGI-CAL® III series of instruments is a family of precision hand held digital thermometers and calibrators for thermocouple-based measurements in the temperature range −200 to +1820 degrees celsius (−392 to +3309°F).

In addition to the direct measurement of temperature, each model in the series may also be used as a precision digital voltmeter in the mV range with 2-microvolt resolution, which permits the calibration and simulation in the field with laboratory precision, of a broad class of temperature-based and other instruments.

1.2 WHERE TO FIND IT

The contents of this manual cover the description, operational procedures and maintenance of all members of the DIGI-CAL III series, these are divided into the following chapter headings.

Chapter 1. Introduction, includes a brief summary of the major performance features, specifications, and ordering code.

Chapter 2. Setup and Operating Procedures, includes step-by-step instructions for use of the DIGI-CAL III as a precision measuring instrument and as a precison calibrator.

Chapter 3. Recalibration, includes step-by-step procedures to recalibrate the mV Range and the Cold Junction Compensation Circuit.

Chapter 4. Routine Maintenance, includes step-by-step procedures for cleaning the instrument and for recharging and changing the battery pack.

Chapter 5. Changing the T/C 1 and/or the T/C 2 Thermocouple Type, includes procedures for changing internal jumpers to set up the DIGI-CAL III for any of the 11 thermocouple types.

Chapter 6. Principles of Operation, includes a brief reveiw of the thermocouple phenomena, as well as the characteristics of thermocouple temperature measurements that impact on the design of T/C instrumentation. The chapter includes a description of the DIGI-CAL III architecture and the performance of the major functional circuit blocks.

1.3 PERFORMANCE FEATURES

1.3.1 Model Types and Features

The present DIGI-CAL III series consists of 3 separate microprocessor based instruments:

AN6503, AN6502, and AN6501

Each model is primarily a precise digital thermometer providing a precision readout using internally stored calibration data, for eleven commonly used thermocouple types. In addition, each model can be switched to operate as a precision digital voltmeter in the millivolt range.

AN6502 and AN6503 feature a set of front-panel key-actuated functions which provide additional flexibility in the measurement mode of operation, these are summarized in Section 1.3.4.

The AN6503, in addition to the measurement features listed above, provides a second set of front-panel key actuated functions for user convenience in setting up the AN6503 as a precision voltage source in the calibration of a wide range of temperature based and other measuring instruments.

1.3.2 Thermocouple Types/Selection for T/C1 and T/C2

Each model in the DIGI-CAL III series includes the calibration table for eleven standard type thermocouples. Internal jumpers set up any 2 of these 11 for rear-panel selection as T/C 1 and T/C 2.

Any two of the 11 thermocouple types can be selected for setup at the factory as T/C 1 and T/C 2 at the time of ordering. Procedures for changing the jumper in the field are described in Chapter 5 of this instruction manual.

1.3.3 The Measurement Functions

A. Temperature Measurements in °C or °F

Each DIGI-CAL III model provides a direct digital readout of temperature. The microprocessor reads the voltage generated by

the external thermocouple, applies the cold-junction compensation correction, and processes a precise temperature readout using stored calibration tables. The user has the choice of selecting either celsius or farenheit scales by front-panel key in the AN6502 and AN6503 models. AN6501, the desired temperature scale °C of °F is specified at the time of order and is set at the factory.

B. Voltage Measurements

By simple switch selection, each DIGI-CAL III is capable of measuring any voltage in the millivolt range connected to the rear input terminals. When monitoring the output of a thermocouple directly in millivolts, the reading is not cold-junction compensated by the microprocessor.

1.3.4 Special Functions — Measurement Mode

As a supplement to the normal temperature measurement functions described above, the AN6502 and an AN6503 models feature a set of three special front-panel key operated functions.

These are —

A. "*HOLD*" which freezes the display at the last reading.
B. "*PEAK*" which samples all the temperature readings, but only displays the maximum value of the first-detected polarity (Peak Magnitude).
C. "*°C/°F*" for the selection of either scale by the operator.

1.3.5 Calibrator/Simulator Mode

The model AN6503 has the additional capability of operating in a calibration mode. Using a set of front-panel key actuated functions, and monitoring the front-panel display, the operator can set a precise, calibrated source voltage for the purpose of calibrating a separate instrument. For example, by setting a temperature reading, a voltage appears at the rear output terminals corresponding to the cold-junction compensated temperature of either thermocouple T/C 1 or T/C 2, as selected. This precise voltage source can be used to calibrate any instrument using the same thermocouple. Alternatively, by switching to the millivolt mode, any voltage in the range can be outputted by setting the display to that reading, and using it as a known source to calibrate a separate instrument. A detailed description of these operations is given in Chapter 2.

THE FOLLOWING TABLE SUMMARIZES THE SPECIFIC FEATURES OF EACH INSTRUMENT IN THE SERIES

MODEL FEATURES

Model	T/C 1	T/C 2	mV	°C/°F	Peak	Hold	Calibrate
AN6501	Y	Y	Y	*			
AN6502	Y	Y	Y	Y	Y	Y	
AN6503	Y	Y	Y	Y	Y	Y	Y

*Programmed to operate in either the °C or the °F mode. Refer to Section 2.4, ORDER CODES and to Section 5 T/C 1 and T/C 2 selection.

1.3.6 Signal Processing

In the temperature measurement mode, DIGI-CAL III measures the thermoelectric voltage (e.m.f.) at the input terminals, applies the cold-junction-compensation for the selected T/C 1 or T/C 2 and displays a precise temperature reading using the stored calibration tables for the specific thermocouple type. Details of these processing steps are given in Chapter 6. The automatic cold-junction-compensation ensures that the accuracy of the instrument is maintained independent of the ambient temperature and results in reference junctions at 0°C for the internally stored calibration tables.

1.3.7 Display Features

The display is a custom designed unit which incorporates all the display functions for the use of all operating modes of the instrument. It consists of a full five-digit, low power liquid crystal display which provides excellent daylight visibility under all operating conditions encountered in the field. LCD arrow annunciators are provided which indicate the mode of operation, and these are identified with labels set in the bezel of the display. Refer to figure 2-3 for locations.

1.3.8 Display Messages

Each DIGI-CAL III features a set of display messages which alert the operator for specific conditions, these are —

Display "HI" indicates that the measured input voltage exceeds the maximum specified for the T/C or mV range. (Refer to Specifications).

Display "LO" indicates that the measured input voltage exceeds the specified lower limit for the T/C or mV range, the input is open, or an open-circuited input thermocouple. (Sometimes called "downscale burn-out".)

The flashing of the battery annunciator on the display bezel indicates the need to recharge the nicad battery pack. Approximately 10 minutes of operating time are available when the low battery indication first appears.

Mode changes by the operator initiate an automatic diagnostic check of the active circuits. At power-on, all 8's, decimal points, and annunciators are displayed. The mode then changes to display all 8's with the required decimal point and annunciators active. This test lasts for two seconds after which the display reverts to the selected mode of operation.

1.3.9 Mechanical Design Features

Each DIGI-CAL III model is assembled in a compact, hand held, rugged, high-impact plastic case which is water and dust resistant. The instruments have been designed for operation in the severe temperature, shock, and vibration environments encountered in adverse field conditions.

1.3.10 Power

DIGI-CAL III is battery powered, using a rechargeable nicad battery pack which provides up to 10 hours of continuous operation. The battery pack and recharger for either 110 or 220 input voltage are supplied with the instrument as standard equipment.

The battery pack is assembled into the instrument and shipped with it as a standard unit. The recharger (for the designated power source), neck strap, a spare input connector, and DIGI-CAL III are packaged in a zipper-sealed vinyl case, and located in the center of the shipping carton.

1.3.11 Accessories

A range of accessories is available as listed in the order code section 1.5 and includes the following items —

Deluxe leather carrying case
Metal stand for bench top operation
Replacement NiCd battery pack*
Replacement recharger*
Assorted service cables
*One is furnished, at no extra charge, with each DIGI-CAL III order

1.3.12 Reliability

The instrument maintains Analogic's traditional excellence for accurate and reliable operation as a result of the exceptional program of quality assurance applied to each stage of manufacture and inspection. These include a rigorous sequence of component burn-in procedures, in-process inspections, and culminating in a carefully controlled product burn-in under power interrupts and temperature cycling.

1.4 DIGI-CAL III SPECIFICATIONS

1.4.1 Measurement Function — Thermocouple Ranges

Thermocouple (T/C) Types
Types J, K, T, E, R, S, B, N. J-DIN, T-DIN and Platinel II
Range, Resolution, Conformity & Accuracy
See Table 1-1
Input Impedance
100MΩ
Source Resistance Effect
– 4μV/350 ohms of resistance (0.14°F error for J T/C @70°F)
Sensitivity
2.0μV/count
Reference Junction Accuracy
Automatically compensated
Maximum error ±0.03°C/°C
Range Tempco
±20ppm/°C typ.
±40ppm/°C max.
Zero Tempco
±0.0003mV/°C typ.
±0.0006mV/°C max.

TABLE 1-1
RANGE, RESOLUTION, CONFORMITY, ACCURACY & STABILITY OF THERMOCOUPLE MEASUREMENT AND SIMULATION FUNCTIONS (ALL VALUES IN DEGREES)

T/C Type (Metals)	°C/°F	Range[1]	Resolution	Conformity[2] ± °	RSS Accuracy[3] (As Calibrated)	Overall Accuracy[4] (after 1 year)
J (Fe/CuNi)	°C	– 185 to 1200	0.1	0.23	± 0.29	± 0.74
	°F	– 301 to – 227 – 227 to 2192	0.2 0.1	0.41	± 0.53	± 1.34
K (NiCr/NiAl)	°C	– 185 to – 175 – 175 to 1372	0.2 0.1	0.23	± 0.35	± 1.00
	°F	– 301 to – 283 – 283 to – 53 – 53 to 1462 1462 to 2501	0.5 0.2 0.1 0.2	0.41	± 0.64	± 1.80
T (Cu/CuNi)	°C	– 200 to – 172 – 172 to + 400	0.2 0.1	0.23	± 0.26	± 0.46
	°F	– 328 to – 277 – 277 to + 22 22 to 752	0.5 0.2 0.1	0.41	± 0.46	± 0.82
E (NiCr/CuNi)	°C	– 200 to + 1000	0.1	0.23	± 0.28	± 0.68
	°F	– 328 to – 253 – 253 to + 1832	0.2 0.1	0.41	± 0.51	± 1.23
R (Pt13Rh/Pt)	°C	– 10 to + 1768	1	0.38	± 0.67	± 1.37
	°F	+ 14 to + 3214	1	0.68	± 1.20	± 2.46
S (Pt10Rh/Pt)	°C	– 10 to + 1768	1	0.36	± 0.71	± 1.52
	°F	+ 14 to + 3214	1	0.64	± 1.28	± 2.72
B (Pt30Rh/Pt6Rh)	°C	+ 600 + 1820	1	0.44	± 0.72	± 1.32
	°F	+ 1112 to + 3308	1	0.79	± 1.29	± 2.38
Platinel II (AuPtPd/AuPd)	°C	– 1 to + 1350	0.1	0.19	± 0.41	± 1.11
	°F	+ 30 to + 250 250 to 1531 1531 to 2462	0.2 0.1 0.2	0.35	± 0.73	± 2.00
J DIN (Fe-CuNi)	°C	– 200 to + 900	0.1	0.21	± 0.26	± 0.57
	°F	– 328 to – 223 – 223 to 1652	0.2 0.1	0.38	± 0.47	± 1.03
T DIN (Cu/CuNi)	°C	– 200 to – 170 – 170 to 450	0.2 0.1	0.21	± 0.24	± 0.46
	°F	– 328 to – 273 – 273 to – 39 – 39 to 842	0.5 0.2 0.1	0.38	± 0.44	± 0.82
N (NicroSil/NiSil)	°C	– 10 to + 1300	0.1	0.22	± 0.33	± 0.86
	°F	+ 14 to + 2372	0.2	0.40	± 0.59	± 1.56

Notes to Tables 1-1 and 1-2

1. For thermocouple calibrate functions, the output range is – 9.998mV to + 99.998mV with resolution and accuracy per the corresponding temperatures shown.
2. Data conformity to ANSI Spec MC 96.1-1975. NBS Monograph 161, DIN-43710, or manufacturers of Platinel II.
3. RSS = the square-root of the sum of the squares of all the error contributions involved at 25° ± 2 C. Stated accuracy is attainable using recommended calibration procedure.
4. Instrument rss accuracy at 25°C ± 10°C, after 1 year.

Noise
<3μV peak-peak (±3σ)
Open Thermocouple
Display reads "LO"
Input Overload
120Vdc or ac rms, continuous without damage

1.4.2 Measurement Function — Millivolt Ranges

Input Range, Resolution & Accuracy
See Table 1-2
Input Impedance
100MΩ
Zero Tempco
±0.0003mV/°C typ.
±0.0006mV/°C max.
Range Tempco
±20ppm/°C typ.
±40ppm/°C max.
Input Overload
120Vdc or ac rms, continuous without damage

TABLE 1-2
RANGE, RESOLUTION AND ACCURACY OF mV MEASUREMENT AND SOURCE FUNCTIONS

Voltage Range	Resolution	RSS Cal. Accuracy[3]	Overall Accuracy[4] (1 Year)
−9.998mV to +99.998mV	0.002mV	±0.01% of Reading + 0.004mV	±0.035% of Reading + 0.008mV

Notes to Tables 1-1 and 1-2

1. For thermocouple calibrate functions, the output range is −9.998mV to +99.998mV with resolution and accuracy per the corresponding temperatures shown.
2. Data conformity to ANSI Spec MC 96.1-1975. NBS Monograph 161, DIN-43710, or manufacturers of Platinel II.
3. RSS = the square-root of the sum of the squares of all the error contributions involved at 25° ±2 C. Stated accuracy is attainable using recommended calibration procedure.
4. Instrument rss accuracy at 25°C ±10°C, after 1 year.

1.4.3 Calibrator (Source) Function (Model AN6503 Only)

T/C Output Ranges
Full range of selected T/C type (see Table 1-1)
mV Output Range
−9.998 to +99.998mV
Setability
2μV or displayed temperature resolution
Reference Junction Compensation
Same as for thermocouple measurement (provided for T/C ranges only)
Accuracy and Resolution
See Tables 1-1 and 1-2
Output Impedance
40Ω typ.
Overload (accidental input overload during Calibration)
3Vdc, 3Vac rms, or short to ground, continuous without damage
Max. Output Current (active pair of terminals accidentally shorted to each other)
Limited to 2.5mA

1.4.4 General Specifications

Warm-Up Time
One minute for 1° T/C ranges or 0.01mV resolution
Fifteen minutes for 0.1° T/C ranges or 0.001mV resolution.
Setting Time
1.2 seconds for rated accuracy
Normal Mode Rejection
Ratio 50dB @ 50Hz or 60Hz
Common Mode Rejection Ratio
Not applicable for battery operation.
130dB signal to earth ground with 250Ω unbalance when recharging
Max. Common Mode
Voltage 250Vac rms, in either battery or recharge mode

1.4.5 Power

Type
Internal nickel-cadmium battery pack, rechargeable. Battery pack included.
Recharge
14 to 16 hours for full battery charge. Unit can be operated continuously while on recharge (+5°C to +40°C)

Battery Life
1000 charge/discharge cycles min.
Continuous Recharge
Indefinitely without damage
Recharge Power
115Vac or 230Vac ±10%
47 to 400Hz (usable below min. line spec.)
Continuous Operation
10 hours typ., 6 hours min.

1.4.6 Mechanical Design

Connector
(Socket) subminiature T/C uncompensated connector, with RJ compensation. Accepts miniature or submin. T/C connectors
Housing
High-Impact ABS plastic, rust color
Weight and Size
21 oz. (0.6kg) nominal with battery
2″H × 5.5″W × 3.75″D
(50mm × 140mm × 95mm)

1.4.7 Controls & Display

Model	AN6503	AN6502	AN6501
Buttons	CAL↑, CAL↓ CALFAST, °F/°C, PEAK HOLD	°F/°C, PEAK, HOLD	NONE
Switches			
Front Panel	2-pos: MEAS/CAL	NONE	NONE
Rear Panel	4-pos:OFF/ TC1/TC2/mV	4-pos:OFF/ TC1/TC2/mV	4-pos:OFF/ TC1/TC2/mV

Annunciators
LCD arrows point to T1, T2 or mV; °F or °C; CAL; PEAK, HOLD, BAT

Calibration
Zero/Span/RJC adjustments. Adjustments accessible without removing unit from case.

Diagnostic Displays

Low Battery

Battery annunciator blinks during a 10-minute warning period, then the unit powers down and the display turns off

Overrange, mV or Temperature

"HI"

Negative Temperature

Underrange mV or Temperature

"LO"

Open Thermocouple Input

"LO"

Display Test

Display reads all "8's" when unit is turned on or range is changed

1.4.8 Environmental & Reliability

Operating Temperature

0 °C to + 50 °C
(+ 32 °F to 122 °F)

Storage Temperature

– 20 °C to + 50 °C
(– 4 °C to + 122 °F)

Relative Humidity

0 to 85%, non-condensing

Moisture Seal

Splashproof panel

Vibration

Each unit vibrated at 5g rms for 30 seconds

Shock (drop test)

Meets the requirements of Mil-Std-202-E for safe transit

Burn-in

> 100 hours min. with temperature cycles from 0 °C to + 50 °C, (+ 32 °F to + 122 °F), and power ON/OFF cycles. Battery pak is installed after burn-in, prior to final calibration.

Calibration

With NBS traceable equipment. CAL certificate supplied with each unit.

MTBF (Calculated)

25,000 hours, excluding batteries and display

Warranty

Twelve months

Operator Safety

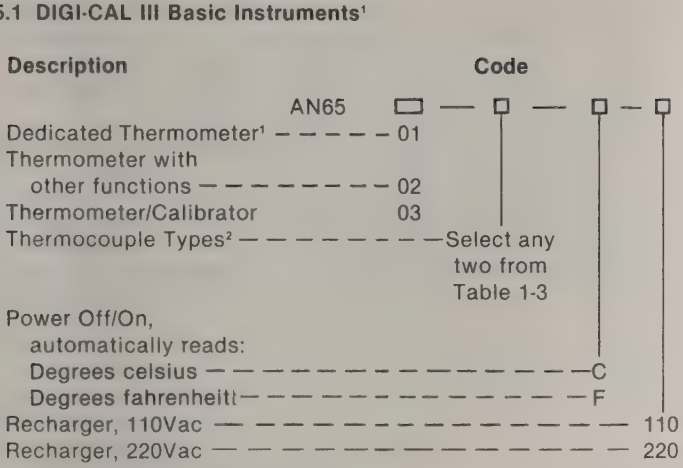
250Vac rms max. on input terminals (relative to earth ground)

TABLE 1-3
THERMOCOUPLE SELECTION CHART

T/C Type	Ordering Code
J	01
K	02
T	03
E	04
N	05
Platinel II	06
J-DIN	07
T-DIN	08
R	09
S	10
B	11

1.5 DIGI-CAL III ORDERING CODE

1.5.1 DIGI-CAL III Basic Instruments[1]


Description
Code
AN65 □ — □ — □ – □
Dedicated Thermometer[1] – – – – – 01
Thermometer with other functions – – – – – – – – 02
Thermometer/Calibrator 03
Thermocouple Types[2] – – – – – – – – Select any two from Table 1-3
Power Off/On, automatically reads:
Degrees celsius – – – – – – – – – – – – – – – C
Degrees fahrenheit – – – – – – – – – – – – – – – F
Recharger, 110Vac — – – – – – – – – – – – – – — 110
Recharger, 220Vac — – – – – – – – – – – – – – — 220

1.5.2 DIGI-CAL III Options and Accessories

Description		Code
Service Cable[4,5] Thermocouple Type	AN65□[3]	-OPT-B-□ J,K,T,E,R,S,B, (See Table 1-3)
Recharger, NiCad	AN65□	-OPT-C-□
110Vac		110
220Vac		220
Battery Pack, NiCad	AN65□	-OPT-D
Carrying Case, Deluxe[6]	AN65□	-OPT-E
Bench Stand	AN65□	-OPT-F
Service Cable Kit[4,5,7]	AN65□	-OPT-G
Instruction Manual	Bulletin No. 16-400052	

Example: AN6503-02-04-F-110, for K and E T/C's for use in U.S.A.

Notes to Ordering Guide:

1. Standard instrument includes NiCad Battery Pack, Recharger, Instruction Manual, neck strap, and mini T/C uncompensated input plug.
2. Although 11 T/C types are internally selectable, choose the two types in ascending order for shipping purposes.
3. Since each option can be used with any model in this series, indicate either 01, 02, or 03.
4. T/C types R and S use alloy #11.
5. T/C type B and mV use uncompensated (copper) cable.
6. Includes belt loop and carrying strap.
7. 1-meter, compensated cable to standard thermocouple connector. Mating male connector provided for cable-connected female.

Chapter 2
SET UP AND OPERATING PROCEDURES

2.1 GENERAL AND SCOPE OF CHAPTER

The DIGI-CAL III is shipped from the factory as a complete, calibrated, operable instrument including internal battery-pack power supply. It is ready to use as a precision thermocouple thermometer, digital voltmeter, or precision calibration source as soon as appropriate input or output connections are made at the rear panel.

This chapter contains information on the setting up and operating DIGI-CAL III in the measurement and calibration modes available in the DIGI-CAL III series.

2.2 SHIPPING CONFIGURATION

Upon receipt of the shipment, inspect the container for any signs of damage in transit, and note especially any evidence of excessively rough handling. Report any apparent damage immediately to the shipping agent.

WHEN YOU OPEN THE CARTON YOU SHOULD FIND (figure 2.1):

- A fully assembled DIGI-CAL III with battery pack installed, battery charger for your specific line voltage, mating miniature thermocouple connector (figure 2-2) carrying case and neck strap, all in a zippered vinyl case. Plus:
- Compressible foam shock absorbing liners.
- This instruction manual.
- Calibration data sheet.
- Range label strip (save for furture range changes.)

The warranty is printed on the inside rear cover of this instruction manual. The calibration sheet and the range labels should be consistent with the model number, serial number and the thermocouple types specified on the range label, and with the item as ordered.

RETAIN THE FOAM LINERS AND CARTON FOR RESHIPMENT, *IF NECESSARY*

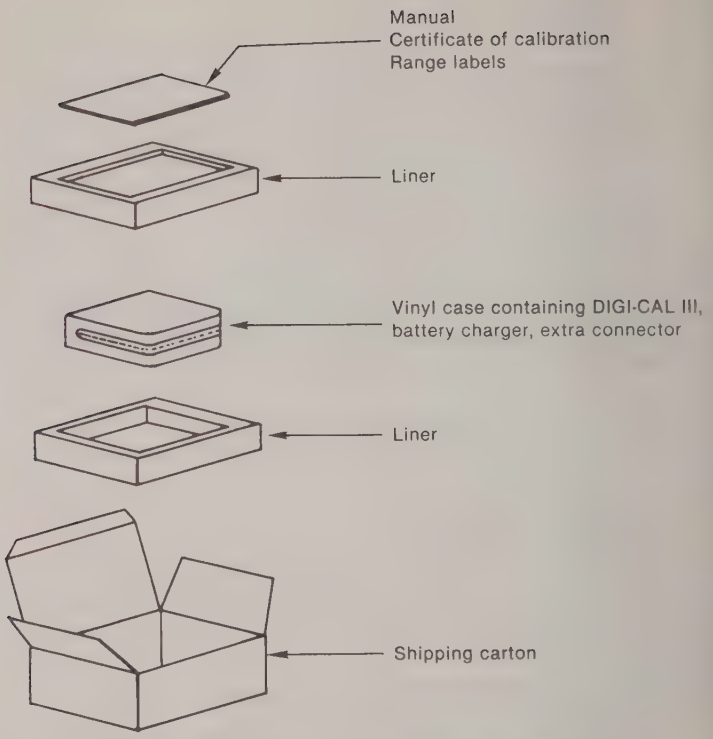


Figure 2-1. DIGI-CAL III Shipping Configuration

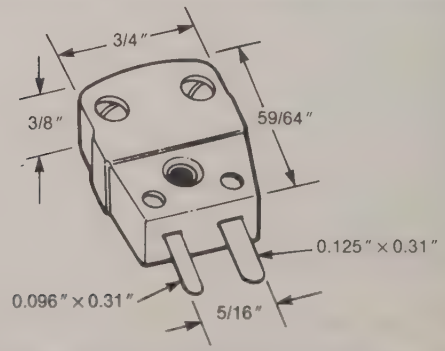


Figure 2-2. Miniature Male Uncompensated T/C Connector

2.3 FRONT-PANEL CONTROLS AND INDICATORS

Figure 2-3 and Table 2-1 illustrate and describe the controls and indicators in a composite front-panel of the DIG-CAL III series. Note particularly the "progressive" performance capabilities incorporated in the AN6501, AN6502, and AN6503 instruments.

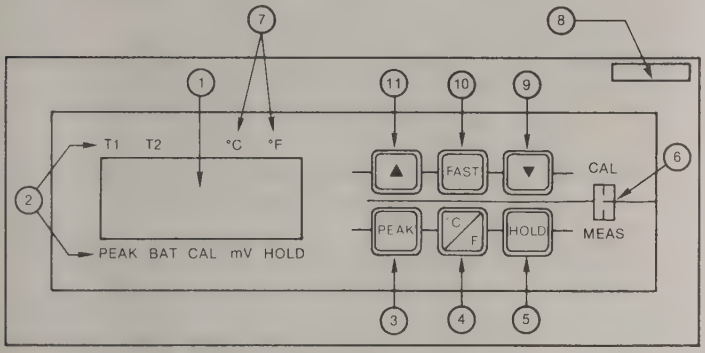


Figure 2-3. Front Panel Controls and Indicators

TABLE 2-1
DIGI-CAL III SERIES COMPOSITE FRONT PANEL FEATURES
(Refer to Figure 2-3)

Ref No.	Feature/Name	Description/Function
1.	Display	5-Digit LCD custom unit, including decimal point, polarity sign, and pointer annunciators.
2.	Performance Status	Bezel-imprinted performance T1, T2, °C, °F, PEAK, HOLD, CAL, mV, HOLD, BAT
3. **	Peak	Membrane-type button. Enabled when slide switch (6) is in MEAS position. Toggles peak detect function in and out of operation. Annunciator arrow points to PEAK in bezel when in operation.
4. **	°C/°F	Membrane-type button. Toggles measurement or calibration thermal units between °C and °F. Appropriate annunciator arrow points to selected temperature units.

TABLE 2-1 (Continued)

5. ***	HOLD	Membrane-type button. Enabled when slide switch (6) is in MEAS position. Toggles HOLD function in and out of operation. Annunciator arrow points to HOLD in bezel when in operation.
6. ***	CAL-MEAS	2-position slide switch, selecting measurement or calibration operational mode. Annunciator arrow points to CAL when in calibration mode.
7.	Temperature Unit	Front-panel identification of factory set temperature unit in AN6501.
8.	Model Number (AN6501, AN6502, or AN6503	Front-panel identification of model unit number.
9. ***	▼ (Decrement Arrow)	Membrane-type button, enabled by switch (6) in CAL mode. Used alone (without FAST), each discrete step decrements the output source by 1 lsd increment. When operated by sustained pressure (without FAST), decrement is slewed at 6.7 steps per second. When FAST is held down (pressed first) discrete decrement is 256 steps; sustained decrement is at rate of 1700 steps/sec.
10. ***	FAST	Membrane-type button when pressed first and held depressed, changes the magnitude of each increment/decrement discrete step or slew rate.
11. ***	▲ (Increment Arrow)	Membrane-type button, enabled by switch (6) in CAL mode. Step sizes, slew rates, without or with FAST button, are same as for down arrow (9).

*Model AN6501 only
**Models AN6502 and AN6503 only
***Model AN6503 only

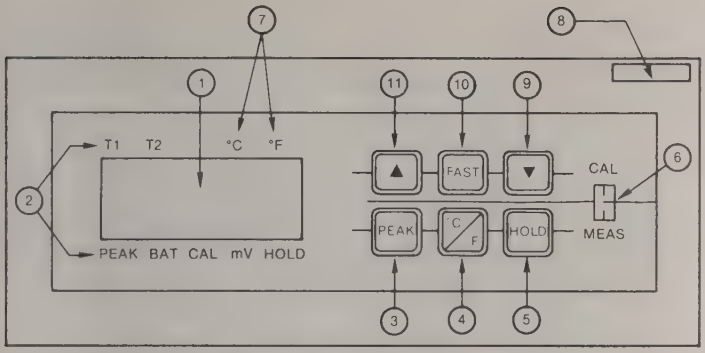


Figure 2-3. Front Panel Controls and Indicators

2.4 REAR-PANEL OPERATING FEATURES

Figure 2-4 and Table 2-2 illustrate and describe the features in all models of DIGI-CAL III performance that are controlled at the rear panel.

TABLE 2-2
DIGI-CAL III SERIES REAR PANEL FEATURES
(Refer to Figure 2-4)

Fig. Ref.	Feature/Name	Description/Function
1.	Remote	Female jack input receptacle. Accepts a switch closure to digital ground or open-collector sink-to-ground signal. Parallels front-panel HOLD operation to hold a measurement value in the display.
2.	Input (Meas) & Output (Cal) connector	Miniature thermocouple connector. Acts as cold-junction for thermocouple measurements or calibrations. Incorporates sensor to obtain cold-junction temperature.
3.	Recharge	Input connector for recharger.
4.	mV/TC1/TC2/OFF	4-position slide switch. Selects form of measurement mode (all models) or calibration mode (mode AN6503 only)

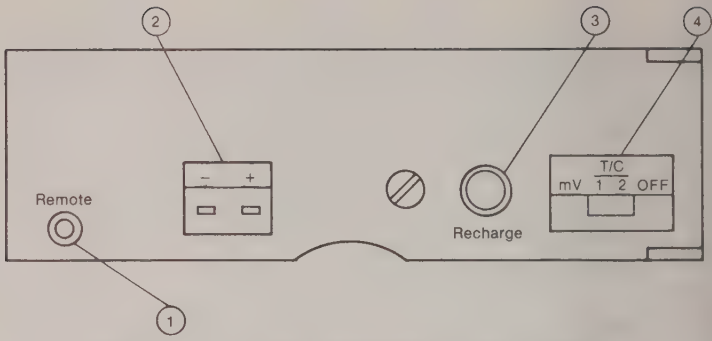


Figure 2-4. Rear Panel Controls and Connections

2.5 CHECKING T/C 1 AND T/C 2 SETUPS

First check that the range label on the underside of the instrument complies with the two thermocouple types ordered (figure 2-5).

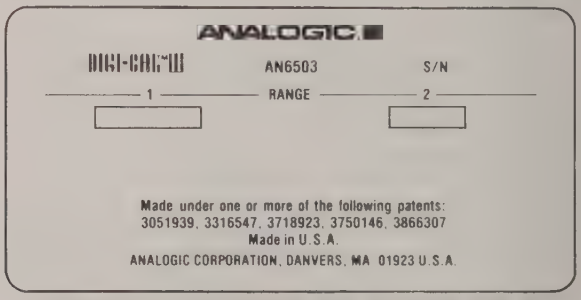


Figure 2-5. Range Label (P/N C11-1837 REV 0)

AN6503 only.

(1) Set the slide switch at the rear to the T/C 1 position.
(2) Simultaneously press the "PEAK" and "▼" buttons on the front panel.
(3) The display will indicate the order code equivalent for T/C 1.
(4) Check the order code (thermocouple selection chart). Section 1.4, Table 1-3, and confirm that the "T1" annunciator arrow is on.
(5) Repeat the procedure for T/C 2. For example a "1" displayed indicates that a type J thermocouple is installed for the T/C selected.

NOTE: The DIGI-CAL III microcomputer automatically sets the lower code number to be T/C 1 and the higher value to be T/C 2, no matter how they were sequenced in the order.

For example, a unit ordered as **AN6503-09-03-F-110** will automatically result as a "T" (code 03) as T/C 1 and an "R" (code 09) as T/C 2.

For AN6501 & AN6502:
If there is some question concerning the T/C selection, open the unit and check the internal jumper selection in accordance with the instructions of Chapter 5.

2.6 SELF-TEST CHECKS

Refer to Figure 2-6.
The test display shown in figure 2-6 is activated each time the rear panel slide switch is moved from the "OFF" position to any operable mode. The display lasts for 2 seconds, indicating that the circuits associated with the specific operating mode selected are functioning correctly. The display also verifies that the complete set of mode annunciators, decimal points, and digit segments are operable.

Following the two second interval, the test display is replaced by all 8's and the appropriate decimal point that remain for an additional 2 seconds. It is then replaced by a correct value (measure or calibrate) for the selected operating mode.

When operating the front-panel MEAS-CAL switch (AN6503) or changing the rear-panel T/C 1, T/C 2, mV slide switch position (without moving to OFF) will cause a 2-second test display of all 8's and the appropriate decimal point.

When a low battery is first detected, the annunciator arrow comes on and points to "BAT" in the bezel. After flashing approximately

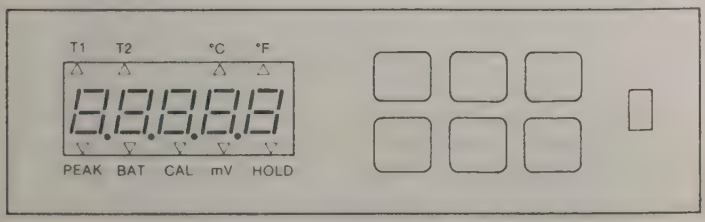


Figure 2-6. Test Display

10 minutes of low-battery operation, the instrument is internally shut off as indicated by flashing 8's test pattern. If the instrument is then turned off for about 5 to 10 minutes, the batteries will usually recover sufficient charge to permit a quick "last reading" before the flashing display is repeated.

2.7 CONNECTING THE THERMOCOUPLE

First verify that the thermocouples you are to use are consistent with those identified on the range label on the underside of the instrument. Connect the leads of the thermocouple to the male connector supplied in the package. The red T/C wire is negative (except for J-DIN and T-DIN). Refer to Table 2-3 for a summary of lead polarity color-coding.

Table 2-3
THERMOCOUPLE WIRE COLOR CODING

Type	Metals	Wire Color (+/−)
J	Fe/CuNi	*White/Red
K	NiCr/NiAl	*Yellow/Red
T	Cu/CuNi	*Blue/Red
E	NiCr/CuNi	*Purple/Red
N	Nicrosil/Nisil	*x/x
Platinel II		x/x
J-DIN	Fe/CuNi	**Red/Brown
T-DIN	Cu/CuNi	**Red/Blue
R	Pt13Rh/Pt	*Black/Red
S	Pt10Rh/Pt	*Black/Red
B	Pt30Rh/Pt6Rh	*Black/Red
mV	Cu/Cu	x/x

*Per ANSI Standard MC96.1 - 1975
**Per DIN 43710 - 1977

Note (1): An adaptor kit is available as option G to connect standard thermocouple connector types to the rear panel miniature type.

Note (2): For all specially assembled cables, the same compensated materials are used to avoid introducing measurement errors. (Alloy 11 is used for R&S T/C's.)

Note (3): Use copper wire to interconnect mV non-thermocouple inputs and outputs, or for the B (T/C).

2.8 MAKING A MEASUREMENT

This section describes standard applications of DIGI-CAL III in the measurement mode for:

- Temperature measurement by thermocouple types using the internal calibration T/C 1 and T/C 2. This is the normal mode of operation.
- Voltage measurement in the mV range of physical parameters other than temperature using appropriate transducers and/or external calibration data.

2.8.1 Mode and Function Controls

A set of controls is provided to permit flexibility in the measurement mode, and they are:

- **T/C 1 and T/C 2 and mV Controls. All DIGI-CAL III Models (Figure 2-4)**
  A four-position slide switch located at the rear of the instrument selects the active thermocouple for temperature measurements, or the millivolt range for independent voltage measurements.
- **Front Panel Control "CAL/MEAS", AN6503 Only**
  This slide switch is set in the "MEAS" position for all measurement mode operations.
- **Front Panel Controls — "PEAK" and "HOLD", AN6502 and AN6503**
  This is a set of toggle-action membrane switches for the following functions. When actuated "peak" enables the operator to determine the maximum value of the input parameter over any time interval.

  At initiation, the existing value is displayed as the first peak value and its polarity is unchanged over the time interval. The display is updated only when the measured value exceeds the magnitude of the value displayed.

  "HOLD" retains the displayed value when activated.

  "PEAK" and "HOLD" are automatically turned off when rear panel slide switch is changed, or when front-panel slide switch is changed from "MEAS" to "CAL".

Note: The "HOLD" function takes precedence over "PEAK". If "PEAK" and "HOLD" are both active, the instrument will hold the last detected peak value. In both modes the instrument continues to process the input signals internally without interruption.

- **Front-Panel Control "°C/°F", AN6502 and AN6503**
  This is a toggle-action membrane switch that changes the temperature scale alternately from fahrenheit to celsius.
- "°C/°F" is not enabled for PEAK, HOLD, or mV modes.
- "°C/°F" may be used when in CAL mode as well as in T/C measurement.
- At power-up (changing slide switch from OFF), the instrument comes up with °C or °F as determined by the order code and factory setting.

2.8.2 Using Thermocouples T/C 1 or T/C 2

Set the rear-panel switch to the T/C range required (T/C 1 or T/C 2), and verify that the front panel annunciator indicates the temperature scale as ordered (°F/°C). In both the AN6502 and AN6503 the scale may be changed by activating the "°C/°F" function key.

For the AN6503 set the front panel slide switch to the "MEAS" position.

In the event that either the 'Hi' or 'Lo' error message is displayed, refer to specifications in Section 1.4, and check the thermocouple connections and the range of measurement.

The display will read the temperature in the selected scale units. Consult Table 1-1 in Chapter 1 for measurement resolution, conformity and accuracy.

2.8.3 Use as a Millivoltmeter

This section applies to the measurements other than temperature.

(1) Connect the measurement transducer to the input taking care to observe the correct polarity. Refer to Section 2.7.
(2) Set the rear slide switch to the mV position. For the AN6503, set the front panel switch to the "MEAS" position.
(3) Read the mV reading. (A display of 'Hi' or 'Lo' indicates that the input voltage exceeds the range −9.998 to +99.998mV). The display resolution is 0.002mV (2 microvolts).

(4) The equivalent value of the physical parameter being measured can then be determined using appropriate calibration tables.

Note — DIG-CAL III can be used to measure the mV output of any low source-impedance transducer or voltage source within the range of the instrument whether calibration is needed or not.

Errors up to 0.010mV per kilohm of source resistance may occur because of the open input sensing current of 10 nanoamperes. This is less than 0.001mV (1μV) for typical sources of 100 ohms or less.

2.9 USING DIGI-CAL III (AN6503) AS A PRECISION CALIBRATION SOURCE

This section describes standard applications of the AN6503 model in the calibrator mode as follows —

- Calibration of other temperature measuring instruments using thermocouples of the same types as those set up as T/C 1 and T/C 2.
- Calibration of other measuring instruments in the millivolt range.
- Calibration of other temperature measuring instruments with types of thermocouples which require external calibration tables (not of the standard 11 in the DIGI-CAL III).

2.9.1 Mode and Function Controls, "CAL" Mode

The AN6503 features a set of three additional controls for this mode. These are —

- **Front Panel Control "CAL"/"MEAS" Figure 2-3**
  This is a two position slide switch which is set in the "CAL" position for all applications in the calibration mode. The AN6503 now functions as a voltage standard source for millivolts directly, or for cold-junction corrected thermoelectric e.m.f., calibrated according to the internal tables.
- **Calibration Controls, ▲ (Up), ▼ (Down) and "FAST"**
  These are momentary-action (or sustained slew action) membrane switches which perform the following functions —
  - ▲ (UP) increases the displayed reading
  - ▼ (DOWN) decreases the displayed reading
  - "FAST" changes the incremental or decremental step or slew values when used with the up/down controls.

- **Interaction of "FAST", "▲" (Up), and "▼" (Down) Buttons** Without the simultaneous actuation of the "FAST" button, the Up and Down buttons may *step* at a specified increment per momentary action, or may *slew* at a specified rate when sustained pressure is applied. When the simultaneous "FAST" button is introduced, the step increments and slew rates are changed as shown in the matrix below.

	WITHOUT "FAST" (Slow)	WITH "FAST"
Step Increment	0.002mV per step	0.500mV per step
Slew Rate	0.013mV per sec.	3.414mV per sec.

In the "FAST" slew mode, the operator can slew from one end of the mV range (−9.998mV) to the other (+99.998) in 32 seconds!

The following steps are recommended in setting a required reading on the display.

- When operating the "FAST" key, be sure to press this key in advance of simultaneously pressing either direction key: ▲ (Up) or ▼ (Down).
- Approach in the "FAST" mode and release the direction key at a precise value within several increments at the desired setting. Do not attempt to anticipate an overrun due to the momentum of the display change since the instrument has the capability to correct for any overrun by retracing to the precise reading displayed at the moment of releasing the control.
- Close in on the desired setting, first using "FAST" direction increments; then "SLOW" slew; and finally, "SLOW" increment steps to an accuracy of one increment.

The operator will find that a short practice will provide proficiency in these procedures.

2.9.2 Simulating Thermocouples T/C 1 or T/C 2

In order to use the AN6503 to calibrate other temperature measuring instruments using thermocouples of the same type as those installed (T/C 1 or T/C 2):

- Disconnect the thermocouple from the input of the instrument to be calibrated.
- Connect the input of the instrument to be calibrated to the rear-panel connector of the AN6503, using T/C wire of the same type. Refer to Section 2.7.
- Set the front panel slide switch to "CAL" and to the correct thermocouple type, using the rear panel slide switch. Verify that the T1 or T2 display annunciator and the range label on the bottom of the unit define the desired thermocouple type.
- Set the temperature scale required using the front panel key (C/F) and check the annunciator displayed.
- Using the control functions, set the temperature to be used in the calibration on the display. Refer to Section 2.9.1 for a detailed explanation of the use of these functional controls.

2.9.3 Setting a Precision mV Source

This section describes the method of calibrating other instruments for the measurement of physical parameters other than temperature in the millivolt range.

(1) Refer to Section 2.7 and connect the signal input of the instrument under calibration to the input of an AN6503, using copper (uncompensated) interconnecting leads.
(2) Set the front panel slide switch to "CAL" and the rear panel slide switch to the "mV" position.
(3) Define the millivolt calibration value, or use appropriate calibration tables to establish the mV values equivalent to the value of the physical parameter to be used in the calibration.
(4) Set the established mV values on the display using the control keys ▲, ▼, and "FAST" on the front panel. This value is supplied as the input to the instrument under calibration.

2.9.4 Measuring Thermocouples Other Than The Eleven In The DIGI-CAL III Series

Equipment Required

Calibrated Thermometer
A set of calibration tables for the specific thermocouple type in use.

(1) Connect the thermocouple (Section 2.7) and position calibrated thermometer closely adjacent to the rear input connector (the reference junction).

(2) Set the rear panel slide to the mV position and check that the mV annunciator is displayed.

(3) If either error message "HI" or "LO" is displayed check the input connections and also verify that the measurement is in the range of −9.998mV to +99.998mV.

(4) Read the temperature of the reference junction on the calibrated thermometer. Refer to Chapter 6 for an explanation of the reference junction.

(5) Using the calibration tables look up the equivalent mV value for this temperature and add the equivalent mV value as a correction to the mV reading displayed.

(6) Caution: Observe polarity signs when combining the correction with the reading.

- Look up the corrected value of the mV reading in the calibration tables to find the equivalent temperature of the thermocouple.

Chapter 3
RECALIBRATION

3.1 GENERAL

DIGI-CAL III is designed for stable performance over extended operating cycles and shelf-life. It is factory-calibrated at tolerances well within the specified conformity and accuracy, and should not need frequent recalibration. To assure the high precision performance of which the instrument is capable, it is recommended that recalibration be checked at one-year intervals. (See Table 1-1 for overall accuracy after one year.) The recalibration consists of:

(1) Calibration of the internal precision reference voltage, for use of the instrument as a precision digital voltmeter in the mV range, followed by
(2) Calibration of the Cold-Junction-Compensation for use of the instrument as a precision digital thermometer and as a precision source of compensated thermoelectric voltage values.

The calibration should be carried out at an ambient room temperature of 71.6 °F (22 °C) ± 3.6 °F (2 °C).

3.2 mV RANGE RECALIBRATION

3.2.1 Required Equipment

A precise 6-digit mV standard instrument, such as the Analogic AN3200 or the Data Precision DP8200, and a grounding strap for the wrist-strap connection.

3.2.2 Procedure

(1) Attach and ground the wrist-strap.
(2) Remove the rear cover to obtain access to the recalibration adjustment controls as shown in Figure 3-1.
(3) Set the rear panel slide switch to the "**mV**" position.
(4) Set the front panel slide switch to the "**MEAS**" position (AN6503 only).

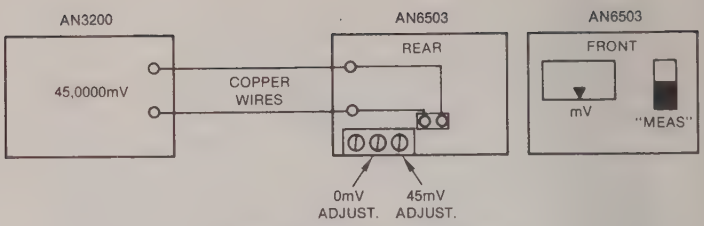


Figure 3-1. mV Calibration

(5) Connect the mV standard to the rear input connector and adjust the standard for an input voltage of 45.0000mV.
(6) Wait 15 minutes for the instrument to stabilize.
(7) Using the mV adjustment shown in Figure 3-1, adjust the DIGI-CAL III display to 45.000mV.
(8) Input 00.0000mV from the standard.
(9) Using the rear panel zero adjustment, adjust the DIGI-CAL III display to 00.000.
(10) Finally, repeat the procedure as a check on the accuracy of the settings.

3.3 COLD-JUNCTION COMPENSATION RECALIBRATION

(Referred to as RJC, Reference Junction Compensation)

3.3.1 Required Equipment

- Ice Point reference (Bath or Cell)
- A calibrated thermocouple of the same type as one of those set up as T/C 1 or T/C 2 in the DIGI-CAL III.

Note: The Cold-Junction Compensation is calibrated *once* for *all* T/C types.

3.3.2 Procedure (Refer to Figure 3.2)

(1) Set the rear panel slide switch to the appropriate T/C position corresponding to the thermocouple in use.
(2) Set the front panel slide switch to the "MEAS" position (AN6503 only).
(3) Using the front-panel "°C/°F" button (AN6503 and AN6502), select either the celsius or fahrenheit scale.
(4) Check the scale annunciators. For the AN6501, note the scale setting °C or °F.

(5) Connect the thermocouple to the DIGI-CAL III using the miniature connector in the prescribed manner.

(6) Insert the calibrated thermocouple in the ice point reference bath (or cell) and allow 15 minutes for the instrument to stabilize.

(7) Adjust the rear panel RJC adjustment to display either 00.0 for the celsius or 32.0 for the fahrenheit scale, plus the correction factor for the thermocouple type in use at 22 °C (71.6 °F) as shown in Table 3-1, plus the correction factor for the calibrated thermocouple.

- **Example:** For A calibrated J-Type thermocouple with zero correction factor, the display should be set to the reading of +000.2 (00.0 + 0.20) if the celsius scale is in use or 32.4 (32.0 + 0.36) for the fahrenheit.

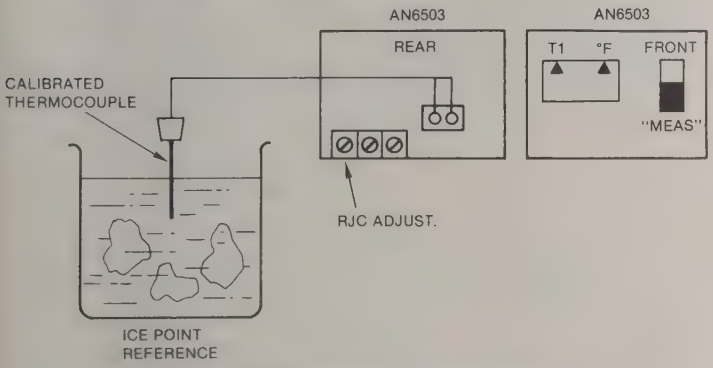


Figure 3-2. RJC COMPENSATION

TABLE 3-1
CORRECTION FACTORS FOR THERMOCOUPLE TYPES

T/C TYPE	CORRECTIONS @ 22°C (71.6°F)	
	°C	°F
J	0.20	0.36
K	0.20	0.37
T	0.16	0.29
E	0.18	0.33
N	0.05	0.08
PLATINEL III	0.13	0.23
J-DIN	0.14	0.25
T-DIN	0.03	0.05
R	– 0.04	– 0.07
S	0.11	0.19
B	*	*

* Not applicable.

Chapter 4
ROUTINE MAINTENANCE

4.1 SCOPE OF CHAPTER

The maintenance tasks covered in this section are

- Routine cleaning and preventive maintenance
- Recharging the battery
- Changing the battery pack

DIGI-CAL carries a 12-month limited warranty, details of which are given in the inside rear cover of this manual. The user should become fully cognizant of the conditions and note specifically that any significant repairs not carried out by Analogic during this period may invalidate the warranty.

4.2 ROUTINE CLEANING

A routine inspection should be done on a regular basis particularly when the instrument is used in a dirty or corrosive environment or when subjected to rough handling. Keep all connector contacts clean and correct loose connectors and switches.

Do not use any solvents that may affect the plastic front panel or "fog" the display bezel (filter). A solution of alcohol may be used for the rear panel cleaning.

4.3 RECHARGING THE BATTERY

The NICAD battery typically will provide 10 hours of continuous operation. The need to recharge is indicated by the flashing of the "BAT" annunciator on the front panel. A full recharge takes 14 to 16 hours, and the battery pack is specified at 1000 charge/recharge cycles before replacement.

Check that the input voltage of the charger complies with your line voltage and make the connection to the recharge connector at the rear of the instrument as shown in Figure 4.1.

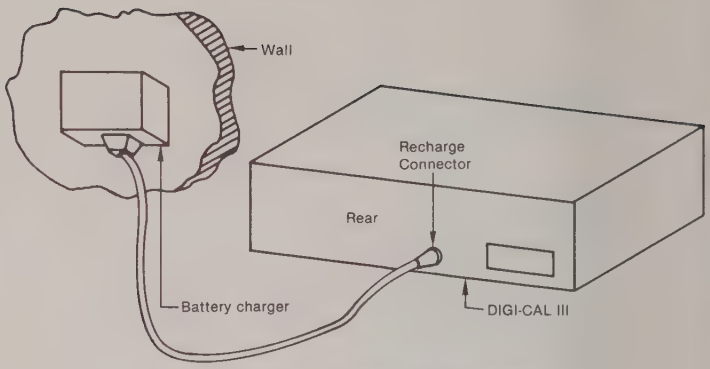


Figure 4-1. Recharging the Battery

4.4 REPLACING THE BATTERY PACK

Replacement battery packs can be purchased from Analogic as an optional item as shown in Chapter 2. To replace the battery, simply:

(1) Check that the instrument is disconnected from all external connections.
(2) Remove the two rear-panel screws and then remove the rear cover.
(3) Remove the battery pack; follow the instructions on the battery pack. Use a coin to pry up and to unlock the snap detent which holds the pack in place.
(4) Slide in the replacement pack, and check that it has positively snapped in place.
(5) Replace the rear cover.

Chapter 5
CHANGING THE T/C 1 AND/OR T/C 2 THERMOCOUPLE SELECTION

5.1 GENERAL

The DIGI-CAL III is shipped so that the T/C 1 and T/C 2 thermocouples are as specified in the order, and the label on the underside of the case identifies the specific T/C types and ranges. Calibration tables for all eleven standard T/C types are incorporated in the instrument, and any of these types may be assigned to T/C 1 and/or T/C 2 at any time. The identification to the microcomputer is accomplished by internal jumpers, and the change is accomplished by relocating the jumpers.

5.2 EQUIPMENT REQUIRED

For this procedure, you will need a Phillips-head screwdriver, a pair of tweezers, a grounding wrist-strap, and replacement labels supplied with the isntrument.

5.3 PROCEDURE

(1) Attach the wrist-strap and connect it to ground to protect components from the build up of static charge,
(2) Remove the bottom screw and slide the electronics out of the case.
(3) Remove the main assembly board by removing the single screw holding the assembly to the case bottom (Figure 5-1),
(4) Carefully slide out the board forward from the case; check that the leads slide free of the mylar shield on the inside bottom of the case. (Figure 5-2)
(5) For the AN6503, remove the calibrator printed circuit board. Hold the board with the thumb and index finger of both hands. (Figure 5-3) Gently rock the board while applying a gentle upward force. This will remove the board easily and with minimal strain on the connector pins.
(6) Locate the socket strips X-1 through X-4 as shown in Figure 5-4. Note that in the case of the AN6503, the X-1 strip is located under the calibrator board.

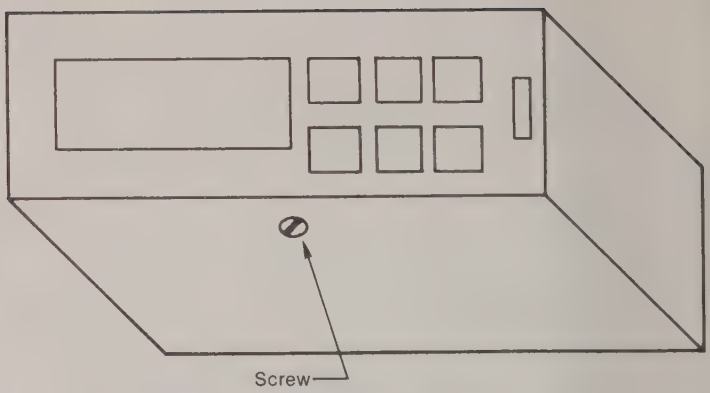


Figure 5-1. Main Assembly Holding Screw

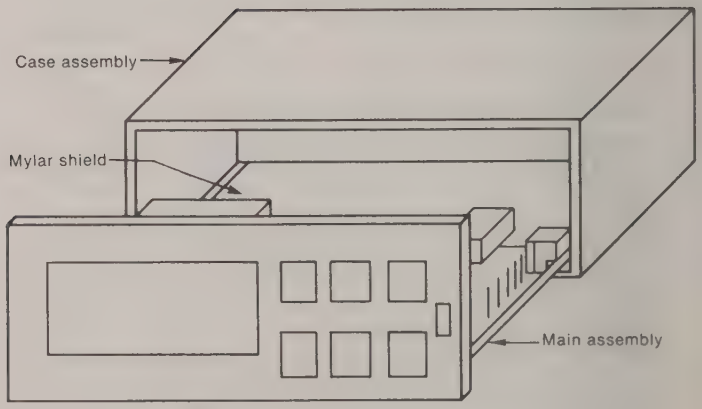


Figure 5-2. Main Assembly Removal

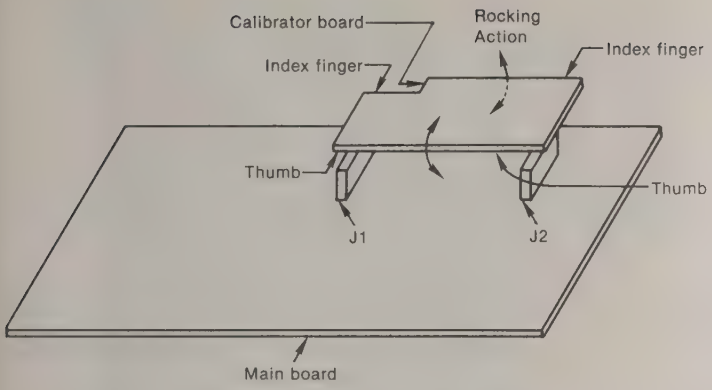


Figure 5-3. Calibrator Board Removal

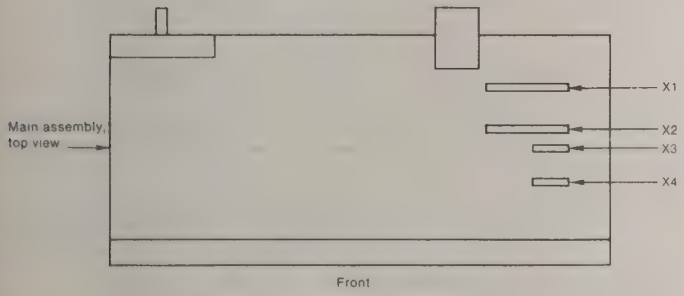


Figure 5-4. Socket Strips X1-X4

(7) Refer to Figure 5-5, and identify the jumper connections for all types of thermocouples specified in the order code.

(8) Note that jumper 12 is used to set the temperature scale as follows:

- For the AN6501, with the jumper 12 installed, the celsius scale is operative. The fahrenheit scale is operative when jumper 12 is removed.
- For the AN6502 and AN6503, with jumper 12 installed, the celsius scale is set in operation when the instruments are switched on initially. Conversely, when the jumper is removed, the fahrenheit scale is initially in operation. In both the AN6502 and AN6503, the scale can be changed simply by toggling action of the front panel button, and the button is operative for either setting of the jumper.

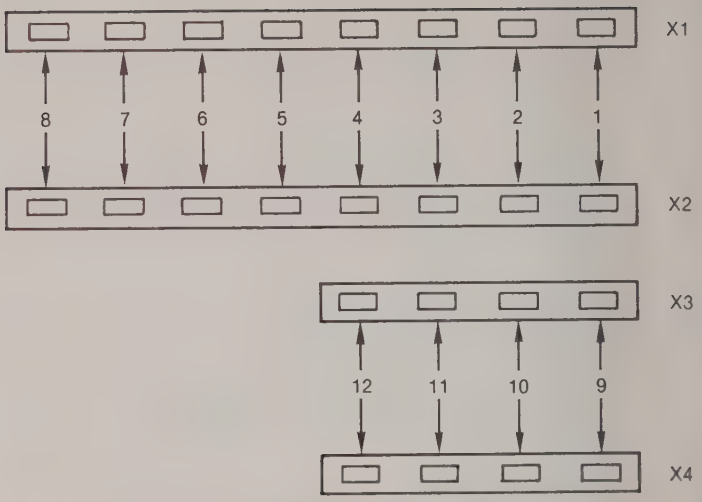


Figure 5-5A. Socket Strip Jumper Locations

(9) Remove the jumper associated with the thermocouple type to be removed, carefully lifting at the center using the tweezers with gentle pressure to avoid damaging the leads.

(10) Refer to Figure 5-5 and insert the jumper in the correct location for the replacement thermocouple. Take care to insert the jumper evenly into the socket by applying gentle pressure at its center using the tweezers.

(11) Reassemble the instrument in reverse order, checking that the calibrator board for the AN6503 is inserted into the socket with the component side facing down and the cutout located as shown in Figure 5-3.

(12) Slide electronics assembly back into case. If bottom screw does not easily engage, press down on boards, using fingers, through battery pack slot in rear of case while pushing the electronics to case from front. Install the bottom screw, battery pack, and rear panel.

(13) Replace the thermocouple range label for the new thermocouple type or types, using the spare set of labels furnished in the shipment package.

(14) For the AN6501, check the proper °C or °F setup, by turning the instrument on and off.

Figure 5-5B. Table of Socket Strip Connector Functions

LOCATION	CONDITION WHEN JUMPERED
1	Type J operative
2	Type K operative
3	Type T operative
4	Type E operative
5	Type N operative
6	Platinel II operative
7	J-DIN operative
8	T-DIN operative
9	Type R operative
10	Type S operative
11	Type B operative
12	Celsius is the default scale

Notes:

Chapter 6
PRINCIPLES OF OPERATION

6.1 GENERAL AND SCOPE

This chapter introduces the principles of DIGI-CAL III instrument operation with a brief qualitative review of the elementary theory underlying the use of thermocouples for accurate temperature measurement and for use as a precision calibrator. For a more complete, quantitative explanation of the thermoelectric phenomenon, a number of comprehensive texts are available.

The instrument operation is described in terms of functional blocks, and significant design parameters are highlighted in their operation.

6.2 THERMOELECTRIC PHENOMENA (Brief Review)

6.2.1 Some Definitions

When two junctions of two dissimilar metals are placed in a non-zero thermal environment, a potential difference (electromotive force, e.m.f.) is developed between the unjoined ends. The magnitude is proportional to the temperature difference between the junctions. (See Figure 6-1A) This is referred to as the thermoelectric phenomenon of a thermocouple.

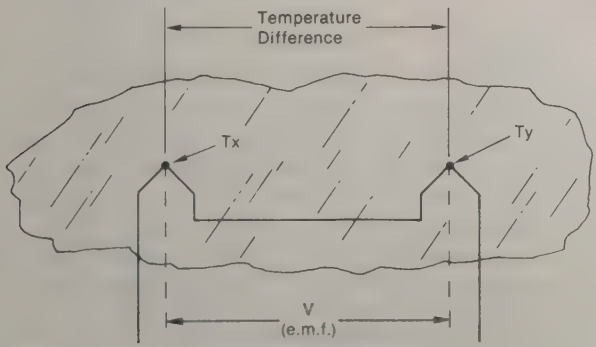


Figure 6-1. Sketch A

When the "ends" are joined (coupled) to the measuring instrument input leads that are usually copper, additional junctions are formed, and these also respond to the effect of the thermal environment at those junctions. (See Figure 6-1B) (This second set of junctions form the "cold" Junction, and more about it later.)

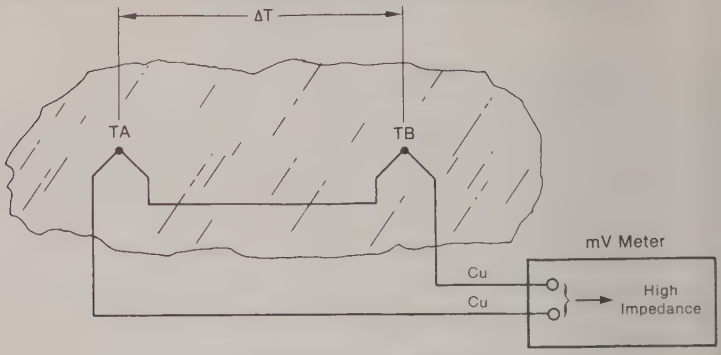


Figure 6-1. Sketch B

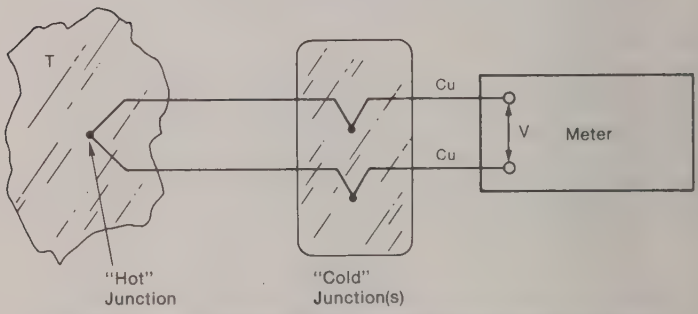
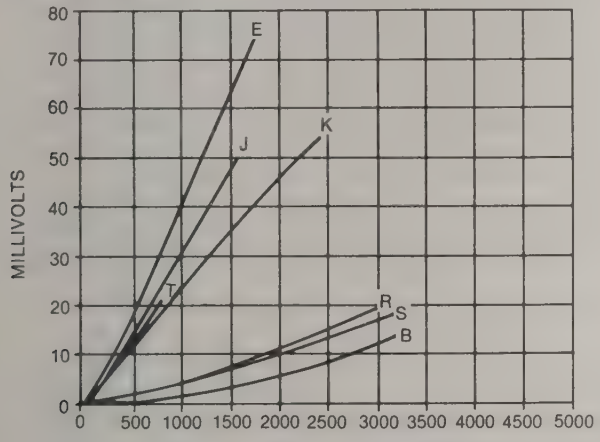


Figure 6-2. Hot and Cold Junctions in a Metering Mode

Since a practical instrumentation requires the use of some meter input leads, the second junction pair cannot be avoided, although their environment may be controlled, or measured more easily than that of the first junction.

In practice, the junction (or couple) not connected to the input of the instrument is referred to as the "HOT" or "MEASURE" (thermocouple) junction, while the second junction pair is referred to as the "COLD" or "REFERENCE" (thermocouple) junction. The measured voltage will be the differential combination of the thermal e.m.f.'s developed by the junctions in the circuit (assuming no

current flow into the voltmeter). When the temperature of the Cold Junction is maintained at 0°C, then the resultant e.m.f. (V in Figure 6-2) may be translated into temperature at the Hot Junction, using standard tables (NSB, DIN, ANSI, etc.) for the precisely controlled chemistry of the metal alloys used. For each thermocouple type, the relationship between Hot Junction temperature referenced to 0°C Cold Junction temperature and the differential voltage may be illustrated graphically, as shown in Figure 6-3. In this low-resolution presentation, the temperature-to-e.m.f. (mV) for each thermocouple type appears to be a linear relationship with a "basic slope".



ANSI SYMBOL

T	Copper vs. Constantan
E	Chromel vs. Constantan
J	Iron vs. Constantan
K	Chromel vs. Alumel
R	Platinum vs. Platinum 13% Rhodium
S	Platinum vs. Platinum 10% Rhodium
B	Platinum 6% Rhodium vs. Platinum 30% Rhodium

Figure 6-3. Temperature - Millivolt Graph For Thermocouples

6.2.2 The Seebeck Coefficient and Conformity

The true slope of the temperature-vs-e.m.f. data varies over the temperature range, and the variation depends upon the thermocouple type. The variation is expressed in terms of μV per degree celsius, and is known as the Seebeck Coefficient.

In order to obtain a precise temperature translation for a measured differential e.m.f., the thermometer must apply this correction to the basic slope. The accuracy with which this is accomplished is indicated by the resultant *conformity*. The conformity specification expresses the maximum variation of the translated differential e.m.f. to temperature from the standard tables, over the specified measurement range.

6.2.3 Cold-Junction Compensation

A typical temperature measuring installation establishes some ambient temperature at the Cold-Junction that is hardly ever at 0 °C (32 °F). Therefore, for accurate measurement of temperature, the instrumentation incorporates an accurate correction to account for the Cold Junction temperature. In the DIGI-CAL III, the temperature of the Cold Junction is measured (using an independent temperature sensing transducer with specified accuracy over the range of operating ambient temperature). Using the stored slope of the thermocouple in operation, the microcomputer generates a compensating e.m.f. so that the Cold Junction appears as a 0 °C (32 °F) Reference Junction, and the compensated differential e.m.f. may be used for Hot Junction temperature calculation.

6.2.4 Applications to Calibration Mode

When the DIGI-CAL III is used as a thermocouple calibrator, the instrument (AN6503) delivers a source e.m.f. at its terminals that must appear to the user as the differential voltage at a 0 °C (32 °F) reference junction. That is, if the user establishes a compensated reference junction at his input terminals (see Figure 6-4), and uses the appropriate T/C wire, then the e.m.f. at the input to his T/C measuring instrument will be equivalent to the temperature Ta set on the AN6503.

When the user Cold-Junction ambient, Tb^1, is different from the AN6503 Cold-Junction ambient, Tb, then the T/C wire leads between the calibrator source and the user instrument will generate a thermal e.m.f. as a function of this differential temperature. The user's Cold-Junction compensation circuit then corrects for this resultant e.m.f. which will be per the T/C standard (ANSI, NBS, DIN, etc.) tables. Therefore, the calibrator generates the thermal e.m.f. equivalent of the displayed calibration temperature for reference junctions at 0 °C and the interconnection T/C wire modifies that thermal e.m.f. to correspond to the required thermal e.m.f. for the user's input terminals.

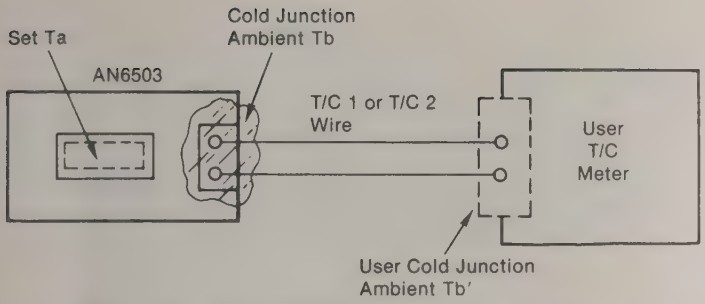


Figure 6-4. AN6503 as a Thermocouple Calibrator

6.3 SYSTEM BLOCK DIAGRAM OVERVIEW (Figure 6-5)

DIGI-CAL III operates in two distinct but complementary modes, — Measurement and Calibration.

In the Measurement Mode, the rear-panel terminals function as input connections, and DIGI-CAL III is basically a precision analog-to-digital converter with a resolution of 2 μV/count over an input voltage range of -10mV to $+100$mV. The thermocouple input voltage is conditioned and then digitized by the converter.

The digital output is then processed by the microprocessor which generates an accurate temperature reading using the calibration tables stored in memory, corrected for the Cold Junction temperature of the input terminals. This Cold Junction correction is derived from a voltage generated by a thermo-sensing element located adjacent to the input connector.

In the Calibration Mode, the operator sets the calibration value required on the display using a set of front panel controls. This value is converted into a millivolt signal which appears at the terminals that now function as output connector with RJC (reference junction compensation) for temperature calibration.

6.4 DIGITAL PROCESSING

When DIGI-CAL III is set to operate in the Measurement Mode, the microprocessor initially scans the rear panel range switch to determine the selected measurement, (T/C 1, T/C 2, or mV) and correlates this with the appropriate calibration tables stored in memory.

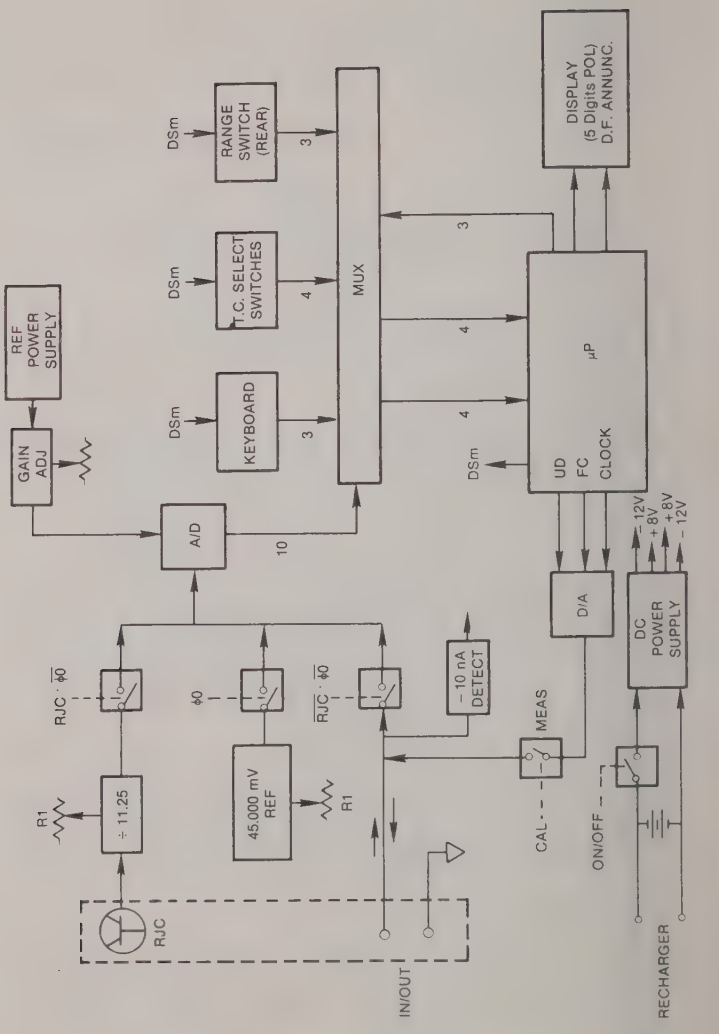


Figure 6-5. DIGI-CAL III Block Diagram

The A/D converter is internally programmed to operate at a conversion rate of 10 conversions every 6 seconds. The thermocouple input signals are digitized in a 9-conversion sequence, and in the tenth conversion, the output from the Cold Junction sensor is digitized. The latter is applied as an offset voltage to the thermocouple voltage to provide an accurate temperature readout. In essence, the Cold Junction compensation maintains the Cold Junction at 0 °C electronically, permitting the calibration tables to provide accurate temperature readout.

6.5 CALIBRATOR MODE (AN6503)

DIGI-CAL III operates in the Calibrator Mode by setting the front panel slide switch to the CAL position. This converts the instrument into a millivolt voltage source of 40 ohms output impedance.

To calibrate a separate thermocouple-based instrument, the operator sets the calibrating temperatures for the selected thermocouple type T/C 1 or T/C 2, using front panel controls. This temperature setting is converted into the corresponding voltage for the thermocouple to be used.

Alternatively, by setting the rear panel slide switch to the "mV" position, the operator provides a calibration voltage in millivolts.

It is important to note that in using the DIGI-CAL III in the temperature calibration mode, the instrument to be calibrated must provide its own reference junction compensation to ensure that the calibration tables are correctly applied.

Also note that in calibrating another thermocouple-based instrument, the connections must be of the same composition as in the thermocouple type in use. The exception to this is when the mV range or when Type B thermocouple is used in which case, uncompensated copper wires can be used.

6.6 DIGI-CAL III THERMOCOUPLES AND THEIR RANGES

The U.S. National Bureau of Standards (NBS) maintains an active program in defining the precise metallic composition of standard thermocouples and in preparing the calibration tables of the relationship between the temperature at the junction and the output voltage. Thermocouples have ANSI-accepted U.S. alphabetic designators. Table 1 in Chapter 2 shows the range for which each thermocouple is calibrated by NBS and the range, within these limits, for which the DIGI-CAL III delivers in-specification performance.

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